eSTEeM Project – Final Report

An investigation into the use of Artificial Neural Networks to predict student failure, and the efficacy of sustainable additional support for those students.

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Executive Summary

The project analysed VLE data with Artificial Neural Networks (ANNs), in order to identify patterns of behaviour that correlate with the likelihood of a student failing the EMA. The ANN models were capable of flagging such students early enough in the module for action to be taken to improve their chances of passing and progressing.

The early stages of the investigation involved collating, synthesizing and processing large datasets from previous TU100 cohorts with the additional aim of significantly increasing the knowledge of patterns of student behaviour. Two crucial steps in this were the selection and pre-processing of the student data, as different parts of the University hold different data in different formats, and derived from differing criteria. After obtaining and feeding the data into the neural networks, the models were refined to determine which of the criteria chosen were most important. This iterative process of training and testing continued until the predictions and observed results from a previous known presentation matched each other. The model was then used as a predictive tool on a current presentation, where it was shown to work well. Doing the same for other modules should be possible, but would require data on those modules and the time to train the models and their users. It is hoped to do some work on this later in 2016/17.

Once the predictions were made, the project showed that personalised telephone guidance from their tutor improves the chances of 'at risk' students passing their module. So if they can be identified, something can be done to try to help them. It has also alerted tutors to the merits of focussing on those students, as that contact has the potential to help them pass the module.

It is important to note that the tutor contact can be triggered by any predictive model, such as those used by OU Analyse, the Information Office, from the Student Support Tool categories, or from a manual selection of criteria applicable to a particular module. So other modules may like to develop that aspect of the project as it involves potentially relevant extensions to the role of the tutor. However, it is important that the tutors are funded for this work, either by an extra payment or (as was done here) by removing an existing activity included within the contact time. Merely adding this to the ever-growing tutor workload is not an option.

The tutor contact also has the extra benefit of encouraging tutors to do something that uses their knowledge of the module and of their students, and which many tutors enjoyed. Consequently, there is potential to extend this so that tutors and Learner Support work more closely in supporting 'at risk', 'fail' and 'cannot pass' students.

Some of these aspects are being continued within TU100, with further development being funded by the MCT Faculty.

Aims and Scope of the Project

Can we predict students that are at risk of failing a module from the VLE metrics available to module teams?

Many TU100 students remain engaged with the module – in the sense of completing the necessary coursework – but subsequently fail the End of Module Assignment (EMA – the examinable component). The overall project aim was to develop software able to spot patterns within a student's VLE activity data that would indicate a danger of such a failure while there was still time to take action. Using data on student engagement around fixed points of a module, such as TMAs and iCMAs can identify patterns of behaviour that indicate the likelihood of a student's passing or failing a module. For example, recent HEA-funded research (Dobbyn & Chetwynd, 2013) showed that students who subsequently fail the EMA employ strategies for completion of iCMAs that are statistically different to those of the cohort as a whole.

Once these patterns have been established and 'at risk' students identified, their tutors can devise interventions that would enable such students to retrieve their situation in time. The individual tutor interventions required were to be included within the existing contact hours for the module, and hence not entail any additional cost (either financial or time) and would focus on students capable of passing and progressing. If this can be done at the right point of the module, that student can be helped, and retention thereby improved.

The overall project aim spilt into three areas to explore:

- The main factors that distinguish an 'at risk' student;
- Whether Artificial Neural Networks can be trained to categorise 'at risk' students;
- What impact the associate lecturer can have on moving such a student from the 'at risk' category to the pass category.

An 'at risk' TU100 student is one for whom early warning signs indicate they are likely to score between 30% and 50% in the EMA (the pass mark being 40%).

Activities

Overall approach

The overall approach was to build one or more Artificial Neural Networks that would accept input data from students' VLE records and output a *prediction* of whether each student's EMA mark would either be a clear pass, a fail, or fall into a borderline category that would indicate a possible failure. The names and PIs of these borderline students would then be passed on to their tutors for suitable intervention.

Planned activities

The planned activities of the project were as follows:

1. To gather appropriate VLE data from three presentations of TU100:
   (a) a historical presentation (2012J) for which student EMA results were already known, to be used to train and test the ANNs
   (b) two 'live' presentations, 2014B and 2014J, for which EMA results were unknown, to be used to test the predictive capabilities of the software and to refer results to tutors.
2. To construct one or more ANNs, together with ancillary software, capable of predicting student's final EMA category from the VLE data, and identifying borderline students.
3. To refer predicted borderline students to their tutors.
4. To evaluate the predictions on the 'live' presentations against actual results.

Details of these activities are given in the next section.

Data and evidence gathered

From the array of VLE data on students' activity and progress, we identified 21 *signifiers*, data items whose values we believed could be predictive of a student's EMA result. This set was then narrowed to 17 signifiers, in three categories, each one encoded in a form acceptable as input to an ANN:

- *Social signifiers*: details of the student's age, background, reasons for studying, etc.;
- *Score signifiers*: student marks on the various assessed assignments;
- *Timing signifiers*: details of late submission, extensions requested, etc.

The 17 signifiers finally selected, along with their possible range of values, and the way these values were encoded, are set out in Table 1.

	Signifier	Possible values	Coding
Social signifiers	Study motivation	• Mainly personal development • Mainly employment/career • Employment/career & personal dev equally important • Didn't specify	1 0.75 0.5 0
	Sponsorship	• Sponsored • Part sponsored • Not sponsored	1 0.5 0
Score signifiers	TMA 01, TMA 03, TMA 04 scores	0 - 100	0 - 1
	iCMA51, 52, 53, 54 scores	0 - 100	
Timing signifiers	TMA 01, TMA 03, TMA 02, TMA 04 late	0 or 1	0 = OK 1 = late
	iCMA51, 52, 53, 54 completed by end of study block to which they apply	0 or 1	0 = OK 1 = not completed

Table 1

It was impractical to select signifiers from any later in the module, as this would allow insufficient time for intervention. Results for TMA 02 were not included, as this was a relatively unchallenging exercise, which did not discriminate adequately between students. This data gathered, broadly the activities outlined in Activity 2 above were to:

1. build a software framework for preparing VLE data for input to an ANN and analysing the results;
2. build and train a number of ANNs, each with different combinations of signifiers selected from the set of 17 detailed above, on the 2012J historical data;
3. Get predictions of EMA category from the trained ANNs for students on the 2014B and 2014J presentations.

The software framework constructed is illustrated in Figure 1. This shows the framework in use in the training phase (Activity 2 above). In Activity 3, the same framework was used, but without training files.

Five networks were constructed and trained to analyse the 2014B data. Based on an evaluation of the 2014B predictions, for 2014J, a reduced set of three networks was used.

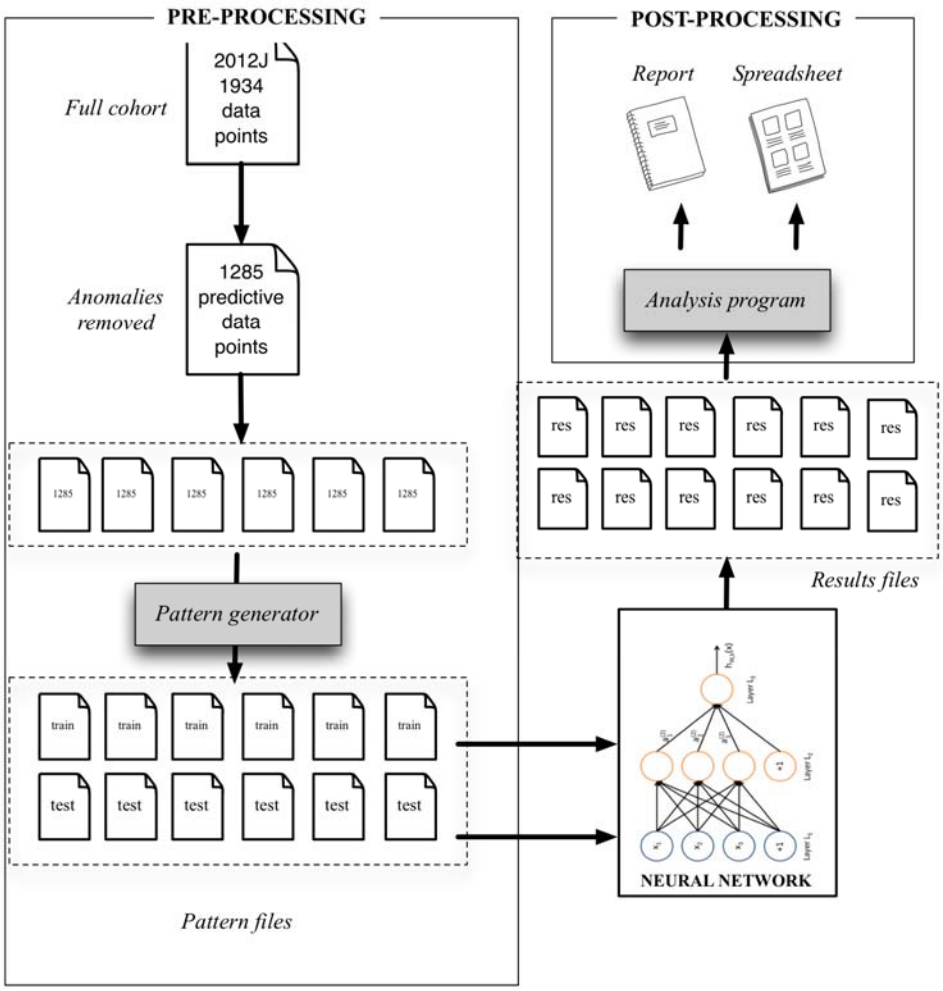

Figure 1

The VLE data required a considerable amount of pre-processing (some details are given below) before it could be entered into an ANN. Similarly, it was also necessary to carry out intensive post-processing in order to obtain a final list of student PIs to be referred to tutors.

Changes made to the plan

Obtaining the VLE data was very difficult, and often required going to separate departments or individuals for the signifiers we wanted.

Once collected, the VLE data was far from perfect. An examination of the 2012 presentation data, for which the students' actual results were known, threw up a number of anomalies, in four categories:

1. **Type 1:** *No data*. Some students remained enrolled for the duration of the module but submitted no work at all. 76 out of the 1934 students enrolled on the 2012J presentation of TU100 were in this category.
2. **Type 2** : *No EMA*. A significant number of students completed one or more assignments but did not submit an EMA. Remarkably, there were many cases of students achieving high marks in all five TMAs and then failing to present an EMA.

3. **Type 3:** *Discrepant TMA and EMA results*. A number of students scored highly in TMAs and iCMAs but achieved very disappointing EMA marks.
4. **Type 4**: *Blank EMAs*. Students who pass the continuous assessment and submit, but fail, an EMA are automatically entitled to a resit, so a small number of students opted to submit a blank 'EMA', scoring 0. In the most egregious case, one student averaged 94.4% on five TMAs but submitted a blank EMA.

Unfortunately, such anomalies are an unsuitable basis for any system that attempts to predict a final result from historical data. All such data points would do would be to add noise to the data used to train the neural networks. Consequently, a filter was constructed to remove anomalies of all four types before any further processing, as illustrated in Figure 1.

Findings

The overall conclusion from the data is that it appears those 'at risk' students who are contacted by their tutor have a better module outcome. Through the project we have alerted tutors to the fact that it is the students that are in the 'borderline' group that it is most worthwhile to contact in terms of helping the students to pass the module.

Right from the start of the project, the intention was always to do something with the results of the model to try to help the 'at risk' students pass in line with the complete learning analytics cycle proposed by Clow (2012). The project team was convinced by personal experience and literature searches that the best approach was for those students to have a personal conversation with their tutor. Consequently, two hours of tutor contact time previously allocated to a synchronous online activity were removed and tutors asked to use the time released to have a telephone or OU Live conversation with up to three students identified by the model. This had two aims:

- to motivate the student to continue with TU100 to the end, and
- to help the student to develop a strategy to pass the EMA at the first attempt.

2013J

On 2013J tutors were given some guidelines to help them choose students to contact. This was because the project had just started and the neural networks were being trained on data from previous presentations. Consequently, there were no predictions to test, but it was decided to run the tutor contact activity, given that a scheduled activity had been removed from the module to release contact hours for tutors to use for the project. The message to tutors included the following:

> ***13J Tutor Activity to motivate TU100 students mid-module***
>
> *This activity should happen during weeks 20 and 21. We ask you to make telephone contact with three of your students who are performing below the average for the group. Do not select students who you consider to have already passively withdrawn from the module for this phone call. When selecting students to ring you may like to take account of:*
>
> - *Bare pass scores for TMA03 and TMA04*
> - *Limited or no completion of iCMAs*
> - *Consistent problems with module assessment deadlines*
>
> *The aim of the phone call is twofold:*
>
> *a) to motivate the student to continue with TU100 to the end, and*
>
> *b) to help the student to develop a strategy to pass the EMA at the first attempt.*

Before contacting your students you may like to develop a plan for the call, and you are welcome to discuss this in the Tutor Help forum. You may wish to arrange the timing of the phone call by email, but please don't conduct the rest of the discussion by email as speaking to students has been found to be more effective.

The tutors chose which students to contact, and were asked to report back on if they were able to have the discussion, allowing the effectiveness of the contact activity and of the simple criteria chosen, to be assessed. Table 2 below shows the module results for this cohort split by whether the tutor spoke to the student or not. Unfortunately, it was unclear whether several of the tutors had been able to speak to the student, either because they did not respond to requests to provide that information, or their response was unclear. This element of uncertainty was a recurring theme throughout the project. However looking at the 278 students for whom we do have data the table shows that 136 (68%) of students who had participated in a phone call with their tutor passed the module, whereas 13 (5%) of the students who could not be contacted in this activity passed.

EMA Result	**Tutor spoke to student**	**Tutor did not speak to student**	**Unclear**
Pass	136	13	6
Fail – offered resubmission	30	2	6
Fail – no resubmission	41	17	2
Withdrawn	19	5	1
Total	226	37	15

Table 2

2014B

On 2014B tutors were given lists of students to contact. Some were listed as 'primary' students who were predicted to fall into a borderline category that would indicate a possible failure. The tutors were also given a list of 'secondary' students who were predicted to fail, but asked not to contact them unless they had less than three in the primary category. Once the results of the module were known, it was possible to compare how the students performed based on the ANN predictions and also on whether the tutor managed to phone them. As can be seen from Table 3, 83 students were predicted to be borderline. Of these 38 (46%) who were phoned by their tutor went on to pass the module, this compares with 14 (17%) who the tutor was unable to contact.

EMA Result	Tutor spoke to student	Tutor did not speak to student	Unclear
Pass	38	14	5
Fail – offered resubmission	4	5	1
Fail – no resubmission	7	5	
Withdrawn	3	1	
Total	52	25	6

Table 3

2014J

On 2014J tutors were once again given a list of students to contact, this time it only targeted students who were predicted to be borderline.
Comparing the prediction with the results it can be seen from Table 4 that 258 students were predicted to be borderline. Of these 99 (38%) phoned by their tutor went on to pass the module. This compares with 68 (26%) who the tutor was unable to contact

EMA Result	Tutor spoke to student	Tutor did not speak to student
Pass	99	68
Fail – offered resubmission	25	14
Fail – no resubmission	13	39
Withdrawn		
Total	137	121

Table 4

2015B

On 2015B tutors were again asked to choose which students to contact and the guidance reinforced by adding:

> **Please do not select students who have already failed OCAS** and so cannot pass the module. Instead those students should be encouraged to talk to Learner Support as they **may** be eligible for a variety of options including deferral and even re-taking the module at a significantly reduced fee. See Section V ofhttp://www.open.ac.uk/students/charter/sites/www.open.ac.uk.students.charter/files/file

s/ecms/web-content/fee-rules-2014.pdf for more details, and use the eSRF facility to refer such students to Learner Support so they can be advised accordingly.

Table 5 shows the results for the students that tutors had selected to try showing the results of the module and whether they did actually manage to speak to them. As can be seen, 120 students were included in this activity. Of these 58 (48%) had a phone conversation with their tutor passed the module, whereas 25 (21%) of those unable to be contacted passed the module.

EMA Result	**Tutor spoke to student**	**Tutor did not speak to student**
Pass	58	25
Fail – offered resubmission	6	11
Fail – no resubmission	13	7
Withdrawn		
Total	77	43

Table 5

In the teaching TU100 does about the use of data in making decisions, it regularly tells the students that 'correlation is not causation' and that is true here as in many other activities that try to improve student retention and completion. A common recurring problem is the lack of knowledge about why some students could not be contacted. Were there extra circumstances meaning that these students were already less engaged with the module, and so less likely to pass anyway? Conversely, were the students who could be contacted more engaged and more amenable to the guidance being given? There wasn't time within the project to look at this, although it is well known that the telephone calling done by Learner Support at various stages of some modules achieves no better than a 50% success rate in speaking to students, even after several attempts.

Impact

Student experience and learning

The project was not primarily about student learning, except broadly in that retained students presumably learn more than students who do not complete the module.

Contribution to increasing student success

This project aimed to highlight to TU100 tutors the names of students who were achieving a pass grade in their TMAs and iCMAs so far, but were at risk of failing the EMA, and thus failing the module as a whole.

Over the past 10 years there has been an increasing emphasis on retention, and tutors have expended much energy trying to contact students who appear to have stopped studying or whose assessment scores indicate that they will not pass the continuous assessment. Whilst these students are important to the University, and knowing their actual status is important, tutors are only rarely successful in encouraging such students to defer their studies, and the rate for deferred students successfully returning to a module is low.

Students who are on track to gain a bare pass generally receive the same support as those doing considerably better. Furthermore, across the wider University, students who pass the continuous assessment but fail the examinable component receive little or no further support for their resit/resubmission attempt. Recent innovations in support for resubmission students on TU100 have been applied across all Level 1 modules in MCT, and have improved both resubmission rates and the chances of passing the second time round. However, a significant proportion of students still do not take advantage of their resubmission opportunity. The simple aim of this project is to get more of this 'pass OCAS/fail OES' group of students over the pass line first time around, using proactive tutor contact and support.

The National Audit Office (NAO, 2007) states that the simple act of choosing a STEM subject reduces students' odds of continuing to a second year, compared to any other subject. Furthermore, students who taste failure are less likely to persist in Higher Education (Lizzio, 2013). However, Bennison (2010), reports that OU students who had either a telephone or email conversation with their tutor during the summer were about 30% more likely to pass the module. The potential points of impact on student success are therefore as follows:

a. Students who would have passed OCAS but who would have failed the EMA, gain a pass in the EMA as a result of discussions with their tutor in the final six weeks of the module;
b. Students who would have failed the EMA and would not have undertaken a resubmission have a greater engagement with the module, thus failing the EMA less badly and feeling sufficiently engaged to resubmit;
c. Students who would have failed the EMA, instead pass the EMA, and are therefore more likely to persist in HE and go on to take further modules with the OU;

Benefits to students not directly involved in the project

Whilst the setting up and use of Artificial Neural Networks, and the analysis of the outputs, is specialised and complex work it is feasible to adapt the techniques described in the report to other modules. The results of trials here suggest that at the tutor-group level, where numbers are small, it is feasible for tutors to select suitable students for proactive contact based on the students' existing performance. Therefore, it would be very easy for other modules across MCT or in fact across the University, to implement a programme of individual pre-submission EMA support for students at risk of failing the EMA, providing the following aspects were tackled:

a. Identify the key indicators of potential EMA failure;
b. Raise awareness amongst the tutor cohort of the benefits of proactive support for this group of students;
c. Make space in the tutor workload to carry out this extra support;
d. Require module teams to engage with tutors to explain the academic basis for the work, what indicators to use in identifying students, when to make the phone calls, what to cover when talking to a student and so on.

In order to realise these benefits to students beyond TU100, the project method and results are now being disseminated more widely, both within the MCT Faculty and beyond. Whilst the sort of proactive work by tutors recommended here can be retrofitted to a tuition strategy, it is much easier to include this work on new modules currently in production.

There seems to be no mechanism for eSTEeM projects such as this to provide early input to module learning design, and therefore it is likely that opportunities are being missed to embed good tuition practice into our teaching.

Teaching

As discussed above, this project required a change in practice for tutors on TU100. Comments made by tutors when the project was rolled out on the 13J presentation gave a clear indication of how the general approach to student support has changed over the years. For example:

"I'm usually very happy phoning students but the bit I'm not quite sure about is what is the excuse for the phone call. Usually it would be a late TMA or similar …. We can hardly go for the truth 'Hi I'm your tutor and you're one of my weakest students' …..I think I need to be a bit more subtle."

And after calling:

"Interestingly all three students were happy to talk about what they were going to do next and none of them suggested that they'd had enough of OU study which is what I was expecting from at least two of them. I pointed them to their StudentHome page and told them to contact their SST to discuss future studies."

"An interesting exercise which wasn't as nerve wracking as I thought it might be."

This aspect of the project stimulated discussions between the project team and the other tutors about the fundamental aim of supporting 'at risk' students. Instinctively, tutors want to see all their students pass, and try to support all of them – even those who cannot pass the module because they have already failed the continuous assessment. One of the points to emerge from the discussions generated by the predictions centred on this issue, and the need to focus most efforts on students who are still capable of passing. All that can be done for those no longer able to pass is to refer them to Learner Support to discuss their options.

Tutors were generally positive about the ideas behind the project, and recognised the benefits that might accrue for the target students. However AL to student telephone contact is not funded, and tutors have expressed reservations about the cost of putting the recommendations into practice. This is especially significant as many students now only only a mobile number, and some tutors have students temporarily or permanently outside the UK, entailing even further expense. While it is possible to use OU Live sessions or third party communication applications such as the free version of Skype (since ALs are not provide with Skype for Business) as an alternative to phone calls, arranging that contact adds an extra layer of complexity to the process. Tutor and student have to agree to be online at a specific time and, depending on the system, potentially also exchange user names before the discussion can be held.

Impact outside of the OU has so far been limited, due to a lack of time to take advantage of dissemination opportunities. However, the use of analytics for enhanced student support in HE is growing rapidly and therefore the project methodology, results and outputs would be of interest to a wider audience, and especially institutions that offer large scale distance learning courses.

Strategic change and learning design

Interest in this project from within the MCT Faculty and elsewhere in the University has been driven by the potential improvements in student retention and completion. That interest has been split between the neural network aspect and the role of the tutor contact part of the project. Coming at a time of increased emphasis on retention and on the use of data analytics to improve and personalise our support for students, the project has been very timely. Indeed it anticipated much of the current interest and has been a pathfinder for aspects of improving retention and support. Now the project has finished, the work has been taken up by the MCT Faculty, who are funding its continuation on the remaining presentations of TU100. This support includes determining the feasibility of training others to use the neural networks on TU100 and on other modules.

Deliverables

Publications:

Woodthorpe, John (2015) 'Improving Student attainments and completion through Mid-Module Tutor Conversations' SST Enhancement Digest, Issue 2, July 2015.

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NAO (2007) Staying the Course: The Retention of Students in Higher Education, House of Commons. Available at http://www.nao.org.uk/report/staying-the-course-the-retention-of-students-in-higher-education/ (Accessed 15 December 2015)

Clow, D. (2012) 'The Learning Analytics Cycle: Closing the loop effectively', *Second International Conference on Learning Analytics and Knowledge (LAK 2012)* Vancouver, BC, Canada, Apr 29 - May 02, 2012. ACM [Online]. DOI: 10.1145/2330601.2330636 (Accessed 6 May 2015).